DOOSAN Document Transmittal

Upper Trishuli-1 HEP (216MW)

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2022-07-17	UT1-HEP-DHI-PC-D-0045	1 OF 1

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SUBJECT	Submission of Review Note RN-0178, RN-0180, RN-0181 and RN-0182		

S. N.	REVIEW NOTE NO.	REVIEW STATUS	DWG. / DOC. NO.	REV.	DWG. TITLE / DOC. DESCRIPTION	REMARK
1	RN-0178	RR	UT1-C-010-CVL-DC-42005	0C	Structural Calculation of Diversion Tunnel Lining	
2	RN-0180	AN	UT1-C-030-CVL-OT-52001	0	Review Report of UT-1 HEP Desander Basin Model Test	
3	RN-0181	AN	UT1-C-030-CVL-DC-52002	0	Procedure for NA for Sediment Deposition and Flushing of the DB	
4	RN-0182	RR	UT1-C-010-CVL-DG-42006	0C	Reinforcement Drawing of Diversion Tunnel Lining	
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Legend of Review Status
A : APPROVED
AN : APPROVED AS NOTED
RR : RETURN FOR RESUBMISSION
FI : FOR INFORMATION

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UPPER TRISHULI-1 HEP (216MW)			
Client	**Nepal Water and Energy Development Company Private Limited**		
Owner's Engineer	**Tractebel Engineering GmbH / Jade Consult**		
REVIEW NOTE			
Contractor	**Doosan Enerbility**		
Title of the Document	Structural Calculation of Diversion Tunnel Lining		
Document No.	UT1-C-010-CVL-DC-42005	Revision	0C
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Review Note No.	**RN-0178**	**Present Review Date**	**15.07.2022**
		Present Review Status	**RR**
A: Approved AN: Approved as Noted RR: Returned for Resubmission FI: For Information, only			

General comments

1. The diversion tunnel is a temporary structure used only during the construction period, so the durability of the Diversion Tunnel is not as critical as for permanent structures. However, due to the high water velocity there is high probability of wearing the lining in a few years or even during one extreme flood event, see as an example figure below.

Example of abrading damage of reinforced concrete due to high flow velocities at Upper Trishuli 3A HPP (source: UT1-C-000-CVL-DD-40003_0A "Design Optimization Proposal-II", figure 2.3-3, page 9)

As the number of Diversion Tunnels has been reduced to one, there is no more a backup existing in case of failure of the Diversion Tunnel.
The contractor shall present a reasonable method statement regarding evacuation of the effected construction sites and recovering plan of the river diversion facilities in case of failure of the Diversion Tunnel to guarantee safety and quick reaction to reduce the impact of such a failure.

2. For this temporary structure, the durability and water tightness is not taken as major issue and the load factors adopted by the contractor are considered satisfactory.(This means, the load factor of EM 2104 is not considered by contractor and only EM 2901 is followed, same has been considered for the review)

It is found that rock loads have been neglected as it would be stabilized prior to the lining. Now the remaining loads are self weight, grout pressure, external and internal water pressure. Though the loading conditions are same (except rock spring stiffness) the section size and reinforcements are significantly different even for the same class rock in the contractor's report.

Though the contractor was requested to recheck the spring stiffness calculation, the spring values are still the same as per previous report. So, the consultant has given the clear calculation in the discussion section and the contractor is suggested to compare their calculation with consultant.

A modeling for concrete lining is done in SAP2000 for class III rock with following inputs:

a) Section size : 500mm
b) Grout pressure : 200 kPa
c) External water pressure : 3*tunnel height = 18m

Following are the results:

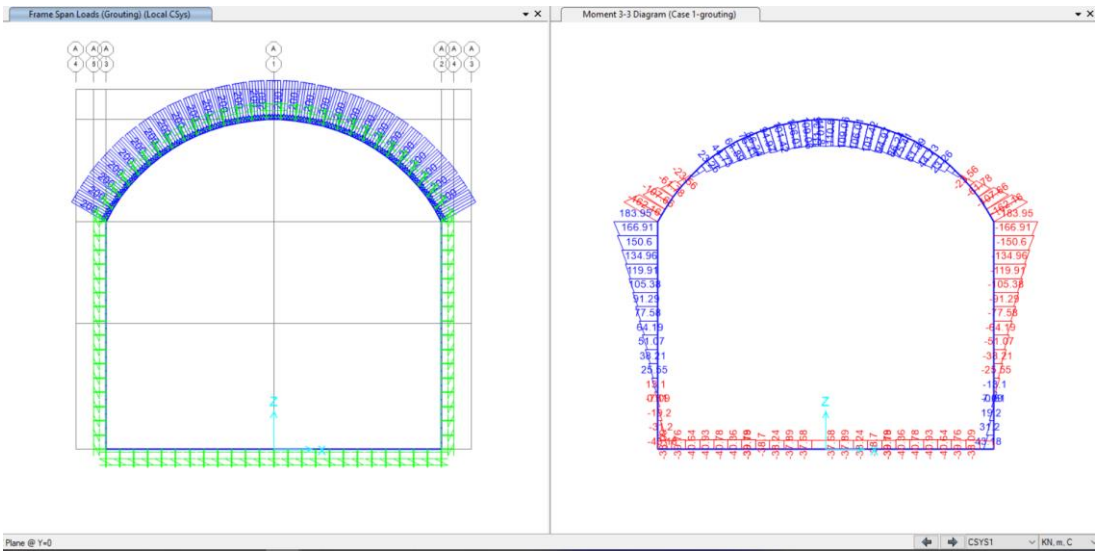

Fig 1: Grout load at the crown only (left), the bending moment diagram for case 1 (right)

Case 1:

1.1 *Self weight + 1.4*Grout load (200 kPa)

The moment diagram clearly shows that singly reinforced section is not adequate due to the presence of both positive and negative moments in the section.

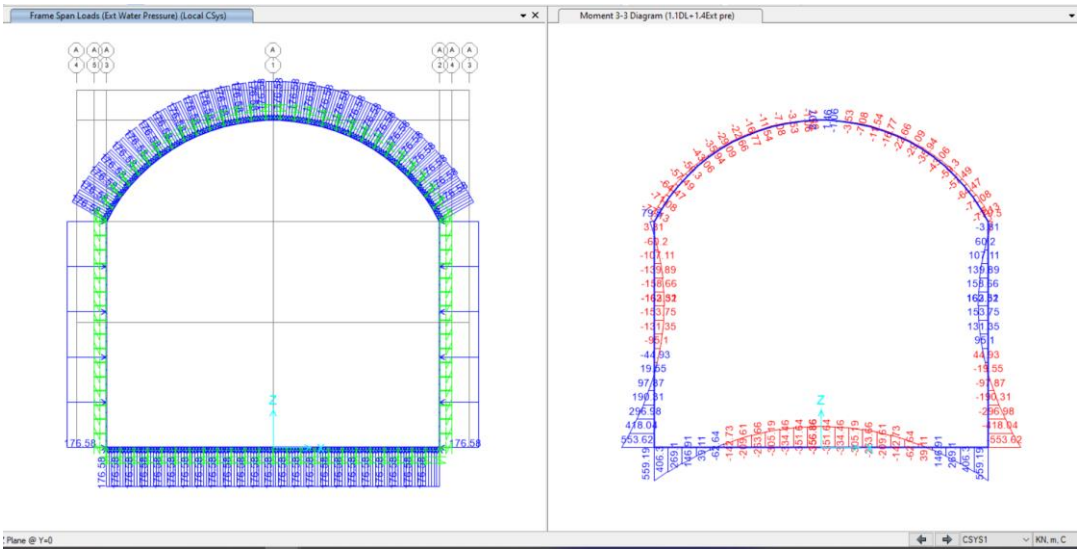

Fig 2: External water pressure (left), the bending moment diagram for plugging (right)

Plugging Case :

1.1 *Self weight + 1.4*External water pressure (18m=3*tunnel height)

So, the calculation gives at least 25mm dia bars @ 155 mm c/c at the base of vertical wall at the rock side. Similarly the bottom reinforcement of base slab demands 25mm dia bars @155mm. But the reinforcement drawing provided by contractor (UT1-C-010-CVL-DG-42006_0C Reinforcement drawing of DT lining) shows the less reinforcement. Besides, it is not clear why the different section sizes have been used for same class rock III. Section sizes of 300mm and 500mm is used for rock class III.

Comments regarding reply comments RC-0048:

In the following text, black color text indicates OE´s previous comments, blue color text indicates Contractor´s reply comments and green color text indicates current OE´s comments.

1) ACI 318-14 is used for design of lining. Since ACI 318-19 supersedes ACI 318-14, it is requested to use ACI318-19 for the design purpose.

Reply: Accepted. Both ACI318-19 and ACI 318-14 can be used in this project.

- ACI 318-19, shall be used for design purpose of the project as there are some changes regarding the shear design, hook length etc. The changes are as per the latest research. Mixing ACI 318-14 will create confusion. In case the contractor's software does not include ACI 318-19 but just include ACI 318-14, then those items which are changed in ACI 318-19 (compared to ACI 318-19) need to be verified manually.

2-1) The concrete compressive strength adopted for lining is 24MPa in section 3.1 (1). a. of the report, but ACI 350-06, clause 1.1.1 requires the minimum compressive strength of 28 MPa for hydraulic structures. Besides, theflow velocity is not considered in design of lining strength. As per the discussion with geotechnical expert, it is found that the flow velocity is greater than 10m/s. As per ACI 210R-06, fig. 3.2, it is seen that 10m/s bottom velocity could transport the particle size of around 800mm and greater. The sediment size might not be so big inour case but there is no any calculation regarding the abrasion of concrete cover thickness. The fig. 3.2 from ACI210R-06 is shown below:

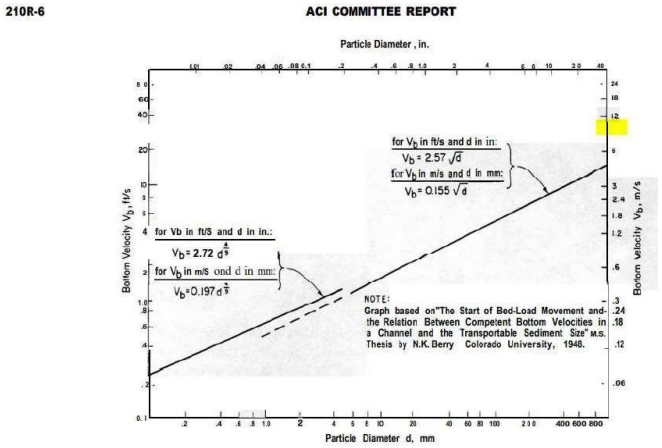
210R-6
ACI COMMITTEE REPORT
Particle Diameter , in.
for Vb in ft/s and d in in:
Vb = 2.57 √d
for Vb in m/s and d in mm:
Vb = 0.155 √d
for Vb in ft/S and d in in.:
Vb = 2.72 d^1/3
for Vb in m/S ond d in mm:
Vb = 0.197 d^1/3
NOTE:
Graph based on "The Start of Bed-Load Movement and the Relation Between Competent Bottom Velocities in a Channel and the Transportable Sediment Size" M.S. Thesis by N.K. Berry Colorado University, 1948.
Bottom Velocity Vb, ft/s
Bottom velocity Vb, m/s
Particle Diameter d, mm

Fig. 3.2-Bottom velocity versus transported sediment size

2-2) The cover dimension mentioned in the section diagram is unclear and seems less than 100mm. Please mention the clear cover adopted for the design of concrete lining in the design report.

Reply: Firstly, regarding applicable standards, as per hydroelectric project engineering practice, the diversion tunnel is a temporary hydraulic structure, contractor deems it's the design should follow EM 2104 and EM 2901

instead of ACI 350, since ACI 350 is mainly related to environment concrete structure requiring high liquid- tightness and gas-tightness such as tank, reservoir.

Secondly, the concrete strength and concrete cover should be determined by considering of the flow velocity and bedload condition, but they are difficult to be determined by calculation.

For concrete strength, as per Employer's Requirement, it is clearly specified that the concrete strength of diversion tunnel is 24MPa. Considering the flow condition of diversion tunnel, contractor himself would like to increase the invert slab concrete strength to 30MPa at his cost, and maintain 24MPa for sidewall and roof lining concrete unchanged.

For concrete cover of invert slab, it can be increased to 150mm.

The use of concrete strength of 30 MPa for the invert of the Diversion Tunnel lining is acceptable. However, the comments under general comments, subchapter 1 of this review note shall be adopted.

2-3) An article titled "Field Investigation on Hydroabrasion in High-Speed Sediment-Laden Flows at Sediment Bypass Tunnels" by Michelle Muller-Hagmann, Ismail Albayrak, Christian Auel and Robert M. Boes, 2020 suggest that for 9.8m/s velocity the average depth of wearing for M110 concrete is around 31mm in operational four years. The maximum wearing depth is roughly twice the average wearing depth, that is, about 62mm as per the paper.

Reply: When the flow velocity inside the tunnel and bedload condition as dam site are considered, 150mm concrete cover for invert slab will be enough.

2-4) This suggests the need to high strength concrete lining the tunnel. Some alternative could be high strength material like Granite layer lining, steel lining etc.

Reply: Please refer to reply 2-2) above.

3) Round bar of 280 MPa is not available in Nepal. Generally 415 MPa or 500 MPa bars are used as shear bars. So, please use the available bars in the design.

Reply: Accepted, 500 Mpa bar will be used.

4) Table 3.2-1, shows the normal and tangential spring stiffness of surrounding rock (Unit length). The beam lengths are divided into arc length corresponding to 5-degree central angle, the spring constant for each beam element needs to be calculated based on that length. However, the provided spring stiffness is calculated for 1mlength and is about 4 times greater than that required for 5 degree arc length. In addition, the discretization lengthof the tunnel at the vertical face and invert level are different as seen from the figure 3.2-2. Please provide the calculation for spring

constant for those parts as per the length of the element.

Reply: In our calculation sheet, the beam length arc is 5 degree, and unit length or 1m should be adopted along tunnel. Please refer to ASCE Vol 2-Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments-Waterways, page 3-47 and 3-48.

- The spring stiffness values in the contractor's report are 4 times greater than the calculation as per EM 2901 formula (9-18). The contractor is requested to verify their calculation with consultant. The screenshot of the calculation is given below:

UT-1: Calculation from Consultant		
EM 1110-2-2901, formula (9-18)		
Spring Constant Calculation for Rock Class II		
Er =	20500	MPa
Mean tunnel radius, r =	2.983	m
Poisson's ratio, ν =	0.25	
Calculation:		
Circumference, C =	18.74	m
Angle subtended by each arc element, θ =	0.08727	radians
Length of element considered, b (flow dirtn) =	1.00	m
kr = Er*b*θ/(1+ν) =	1431170	kN/m
=20500*1000*0.08727/(1+0.25) =	**1431170**	**kN/m**
kt = 0.5*kr/(1+ν) =	572468	kN/m
=0.5*1431170/(1+0.25) =	**572468**	**kN/m**
As per the contractor's report		
kr =	**5857143**	**kN/m**
kt =	**2342857**	**kN/m**

5) Table 3.3-1 considers the grout pressure on the design but the value adopted for the grout pressure is not mentioned in the report. Please provide the grout pressure considered for the design.

Reply: Accepted. The backfill grouting pressure is 0.2MPa, using maximum permitted grout pressure over area equal to one-quarter the tunnel diameter, as per item 8 in Box 9-1 of EM 2901.

- OK

6) If excavation is to be carried out by explosive then horizontal force needs to be increased by 30% as per EM 1110-2-2901, Box 9-1. But 3.3.2 (1) does not consider extra 30% load. If the explosives are not to be used, please mention the method of excavation.

Reply: As per EM 2901, page 9-7, item f, the rock is stabilized at the time the concrete lining is placed, and there are four circumstances when other loads are considered. To the diversion tunnel of this project, none of them is applicable, so the rock load will be not considered in the calculation, and this calculation will be revised without considering rock load.

- For the stabilized rocks it is satisfactory.

7) As per EM 1110-2-2901, cl 9-1h, with proper drainage, the external water pressure shall not be taken less than lesser of 25% of the existing external water pressure and three tunnel diameter due to the possibility of clogging. The value adopted for external pressures seem to be very low as per the report. Besides, the minimum external water pressure as per EM 1110-2-2901 cl 9-1h is 18m in our case.

As per EM 1110-2-2901, cl 9-4d it is reasonable to consider external water pressure equal to internal water pressure. The internal water pressure ranges from 16.5m to 28.5m. Hence, the contractor is recommended to adopt the external water pressure value of higher of 18m and internal pressure at the section. So please revisit the calculation.

Reply: Comments accepted.

After careful analysis, contractor consider that the control condition of lining is construction case. The reason is as follows:

In the plugging case, the external water pressure may be plays a controlling role. According to construction schedule, the plugging construction may be lasted within 2 months. Meanwhile, the plugging is arranged in March belong to dry season; the water level is lower. The possible external water pressure acting on concrete

lining is small. Even if there is a large water pressure, the concrete cracks will not be a safety risk. Once the plugging is completed, the diversion tunnel will lost its function and need no further care.

- The load case for plugging (1.1 self weight + 1.4 external water pressure) is eliminated in the updated report. The screen shot from contractor's report is given below:

Table 3.3-1 Operation Conditions and Relevant Loads

No.	Working Condition of Calculation	Self-weight	Internal water Pressure	External water Pressure	Grouting pressure
CASE1	Construction of D/T	√			√
CASE2	Normal operation	√	√	√	

Note:

1. For lining and segment lining with weep holes, the internal pressure equals to the external pressure, thus the water pressure acting on the lining takes zero. However, for lining and segment lining without weep holes, external water pressure is not considered.

2. As for the lining without weep holes, the counteracting effect of external water pressure on internal water pressure is not considered. The force acting on the lining adopts the whole internal water pressure.

However, in general it is the governing case and generally shall not be eliminated as per EM 2901, section 9-1h. The related screen shot from EM 2901 is given below:

instituted to reduce the flow. The lining should be designed to withstand a proportion of the total external water pressure because the drains cannot reduce the pressures to zero, and there is always a chance that some drains will clog. With proper drainage, the design water pressure may be taken as the lesser of 25 percent of the full pressure and a pressure equivalent to a column of water three tunnel diameters high. For construction conditions, a lower design pressure can be chosen.

If in case the construction schedule varies or if the ground water table is higher than expected, than eliminating external water pressure would be problematic.

8) The roof water reduction for intersection provided in table 3.7 is not matching with figure 3.3-3. Please revisit the calculation.

Reply: the external pressure calculation method is changed to OE's commented method; the calculation has been revised.

9) The crack width calculation for the lining is not provided in the report. In order to avoid the crack check the load combination shall be multiplied by environmental durability factor (Sd) as per ACI 350-06, clause C.9.2.9.

Reply: Please refer to reply to 2-2) above.

- OK

10) The minimum reinforcement As, min shall fulfill the requirement of ACI 350-06, Table 7.12.2.1. Though the reinforcement will be checked only after incorporating the comments, it is seen that the reinforcement provided does not meet the requirement of minimum requirement in some places.

Reply: EM 2104 is a specialized standard for hydraulic structures, so we will follow EM 2104 in determination of shrinkage reinforcement. Contraction joints will be applied with a space of 6.3m, and the minimum shrinkage reinforcement ratio takes 0.003.

- The EM 2104 and ACI 350-06 agree with each other. Though the load factors adopted for this structure is not as per EM 2104, it is considered satisfactory as the governing aspect will be rapid wearing of concrete rather than durability. If contractor assures that the work will continue even if diversion tunnel stops working then the minimum reinforcement is not an issue.

11) Please provide the software files (Phase 2D and Midas Gen files) used in this report, so that it could be verified quickly.

Reply: The software files (Phase 2D and Midas Gen files) used in this report is attached in the mail for quickly verifying purpose.

- OK

12) With respect to further design of tunnel liners of the waterways at UT-1, a more up-to-date model could be used to verify the results from Midas Gen software. The spring model is certainly from an analytical point of view, correct. However nowadays there a computational model available which provide more insight view of the conducted analyses. The designer is using the PHASE2 code for the seepage analyses, already. With this tool (more) adequate calculations can be conducted for the tunnel liner.

Reply: Noted.

Some changes observed in the new report

- The updated report has adopted the internal water pressure as 16m only where as it was 28.5m in the earlier report. What is the reason beyond that?

DISCLAIMER

Any approval will not release the Contractor from any of his obligations under the Contract. Despite the Engineer's approval the Contractor remains fully responsible for design, calculation, dimensioning, supply and installation without limitations.

Dr. Subin Desar (Structural Engineer)

Sebastian Beck, Chief Design Engineer